Bacterial migration through the teat canal related to liner action.

W. Gehm[1.], D. Forbes[2.].

1. LR Gehm LLC, 9502 NYS Rt. 79, Lisle, New York 13797, USA

2. The Villa, Wincle, Macclesfield, Cheshire, SK11 0 QE

The mechanism by which bacteria penetrate the teat canal (TC) is not fully understood. Early work (1) had shown that some TCs were infected for long periods before the bacteria reached the teat sinus.

Subsequent work (2) used naturally occurring infections of the TCs in an experimental dairy herd to further investigate the development of intra-mammary infections (IMI). The infections were mainly staphylococci and micrococci (*Micrococcaceae),* all non-motile cocci and commensal organisms of skin. Using methods to recognise all subgroups of the organisms, it was possible to monitor their distribution in the TCs and milk of the herd. The assumption was made that the mechanism by which they penetrated the TC was the same, and independent of their intra-mammary pathogenicity.

Materials and Methods.

Teats were first cleaned with swabs soaked in methylated spirit.

- TCs were swabbed by a cotton bud penetrated 3mm into the canal and then rinsed in 5ml of 1% glucose broth.
- 10ml of foremilk were collected in a sterile container.
- 1ml of teat sinus milk was collected by syringe through the teat wall. (3)
- 0.1ml of swab inoculated broth or milk were sown onto 5% sheep blood agar plates containing aesculin, incubated for 48 hours at 30°C and refrigerated overnight before being read.
- Cores of keratin were harvested from TCs in Portex tubing. (4)

Bacterial typing.

Micrococcaceae were typed using physiological and biochemical tests. (5)

S. aureus strains were identified by phage typing. (6)

Other organisms were recognised by colonial morphology.

Results

Survival of bacteria in TC keratin

- Keratin was collected from TCs with known infections. The samples were incubated for 60 days in a humid atmosphere. The bacteria were harvested and typed at intervals. All organisms survived at least 7 days and some for 60 days. From some samples, strains were isolated after prolonged incubation that had not previously been detected by swabbing. In some cases the donor TCs were then found to have the same strain *in-vivo.*

TC epidemiology

- TCs of a herd of 25 cows were swabbed weekly for 40 weeks. Bacteria were typed when more than 25 colonies were present on a plate.

  Although many colonies had similar colour and morphology, typing showed them to be of many different subgroups.

  TC infections were of several weeks duration occurred commonly although others were transient.

  Different subgroups dominated at times during the observation period.

Pathogenesis of mastitis.

- Foremilk samples and TC swabs and were taken weekly from all quarters of 18 cows.

  IMIs were identified by culturing teat sinus milk taken 1 week before calving, 8 weeks following calving and thereafter at 4 week intervals.

  S.aureus caused IMIs in 11 quarters and was widely distributed in other TCs. One strain was isolated from 18 TCs over periods of at least 3 weeks from quarters that never developed IMIs. One quarter had a TC infection at the start of lactation which persisted and an IMI was not confirmed until week 20.

  Only 3 strains of coagulase negative staphylococci caused IMIs and all followed localised TC infections.

Conclusions

The overall conclusions from this work can be summarised as follows;

- The TC and its copious waxy keratin is an ideal environment for commensal skin bacteria.
- Those bacteria can also become IMIs and depending on their pathogenicity cause clinical or sub clinical mastitis.
- The evidence showed that infections in the canal can be long established without necessarily leading to an IMI.
- IMIs are often preceded by localised TC infections of some duration.
- The dynamics of bacterial populations within the canal cannot be systematically investigated.
- Passage through the canal may be by bacterial growth, and/or mechanical transportation.

Discussion.

Evidence from the literature suggests that teats with certain characteristics, particularly of length and diameter, and especially conformation of the end of the teat, have a predisposition to mastitis. It is recognised that keratin can be extruded through the teat orifice due to the pinching action of the teat cup liner during machine milking. The pathogenesis of mastitis is a dynamic process but essential in that process is the traversal of bacteria through the TC.

Data reported here of the relationship of TC infections and the passage of bacteria through the TC into the teat sinus, suggests that it is the culmination of a process and not a single event.

This led to the hypothesis being postulated that in some teats, depending on their size and shape, the action of the teat cup liner on the apex of the teat could cause keratin to be intruded in the canal towards and into the teat sinus. If that keratin was infected then that could be the mechanism for the introduction of bacteria into the intra-mammary environment with the consequent risk of mastitis.

If a milking machine could be invented that did not allow complete collapse of the liner, thereby avoiding pinching of the teat end, then the carriage of bacteria through the TC would not occur.

The work reported here relates to bacteria that are now described as 'contagious' mastitis organisms whereas the predominant cause of clinical mastitis is now due to 'environmental' bacteria, most of which are motile organisms. If the natural integrity of the TC can be retained it is likely that the ability of environmental bacteria to traverse the canal will be diminished. This could be significant, especially considering the exposure of the teats to environmental infections associated with modern herd management practices.

The development of a milking machine with a new liner action. (CoPulsation™)

There exists a number of objective observations to be made relative to the interaction of milking machine with the animal being milked that provide additional insight into the discovery and data provided above. Research at Teagasc (7) has shown that cows milked with conventional milking machines experience teat tissue swelling and teat canal damage, termed teat sinus injury by those researchers. A visual observation of cows milking confirms the teat swelling and reddening of the external teat tissue and also that the teat exterior is wetted with milk following the milking process indicating a possible mechanism for transfer of bacteria to the teat during the milking process.

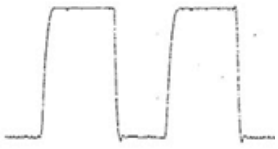
It is possible to physically feel the liner pinch, or crushing, action by placing ones fingers into the liner of a working milking machine. This exercise enables one to feel both the localization of the liner pinch at the teat end as well as the sustained vacuum application during the rest phase that contributes to teat swelling and teat canal/sinus injury.

A more detailed investigation into the dynamics of liner action and the resulting impact on the teat canal has been completed to further the above noted research. The alternating application of vacuum and air to the pulsation chamber causes the liner to open and close. The small difference in diameter between the liner interior and exterior permits the movement of the liner even with an applied vacuum equal to that of the vacuum at the liner interior. However, this small difference in diameter combined with the physical presence of a teat within the liner results in a very small available energy to move the liner to a desirable closed position for a proper rest action.

The investigation started with a measurement of the duration of the pulsation C phase (liner closure phase) as measured at the pulsation chamber. It was noted that the typical C phase duration is in the 100

millisecond to 160 millisecond range. Further investigation revealed that the stiffness of the liner also plays a role in both the C phase duration and the closure of the liner. It has been determined that a C phase duration in the 40 millisecond to 60 millisecond range combined with a low closure force liner will result in a dramatic change in liner dynamics.

C Phase 120 milliseconds



C Phase 50 milliseconds

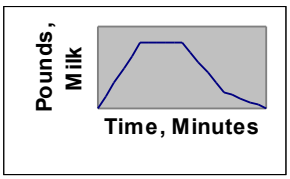
This combination will cause the liner to close in a manner that results in a light compressive force being applied to the full length of the teat as opposed to concentrating the closure on the teat end with a pinching/crushing action. The full teat length closure provides relief to the full teat from the interior liner vacuum allowing for the natural flow of fluids from the teat thereby eliminating congestion and the swelling and pain commonly caused by conventional milking machines. This action is most similar to the results achieved by the use of compression socks on individuals with poor leg circulation.

Research has been completed using a milking machine capable of providing a C phase of 40 to 60 milliseconds in the pulsation chamber with the combined use of a low closure force liner. That research has shown that teats are typically smaller in diameter following machine removal instead of larger as demonstrated by Teagasc researchers (7) when using conventional milking machines.

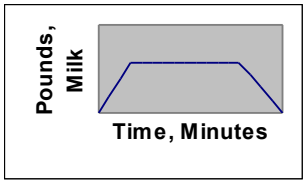
A detailed investigation of the resulting wear of liners proves that a difference in liner action exists. Identical liners were used in both the short C phase milking machine and in a typical conventional milking machine. The end of life liners used in the short C phase milking machine exhibited wear characteristics demonstrating a full teat length compressive massage. The same liners used in a conventional milking machine did not show evidence of a full teat length massage.

Liner comparison: Same liner, two on left used with short C Phase machine, liner on right used on conventional C phase machine

The effect on milking performance was also evaluated using the short C phase milking machine. The rate of milk removal was measured as a function of time and compared to the typical milk removal rate achieved with a conventional milking machine. It was discovered (8) that the milk flow rate with the short C phase milking machine was at a uniform peak flow rate for the majority of the milking duration with limited durations of ramping flow rate at the start and cessation of the milking process. Cows milked with a conventional milking machine experience a limited duration of peak flow rate followed by a long period of ramping reduction in flow rate.



Flow rate: conventional



Flow rate: short C phase machine

The cumulative result of these changes is a reduction in mastitis infection rates and improved udder health. Initial research proved a reduction in new contagious mastitis infection rates by nearly 16:1. It was demonstrated that new Staph. aureus infections were virtually eliminated in a one year side-by-side study (9) of a group of 30 cows. A later similar study (10) was completed over a multi-year time period with a similar number of cows on a small commercial dairy farm. That research again proved a similar reduction in new contagious infections and also proved a similar reduction in environmental mastitis infections.

It has been demonstrated in these two research efforts that a short C phase milking machine reduces new infection rates. Substantial reductions in contagious rates can be achieved in the short term with environmental infection rate reduction requiring sufficient time for the teat canal health to be improved.

References.

1. Forbes, D and Hebert, C. N. (1968). Studies in the pathogenesis of staphylococcal mastitis. Vet. Rec. 82 69.

2. Forbes, D. (1968) Studies of the infection of bovine teat canals, their epidemiology and role in the pathogenesis of mastitis, Ph. D thesis, University of Reading.

3. Murphy, J.M and Stuart, O. M. (1954). The syringe collection of milk via teat wall puncture as an aid in the study of artificial infection of the bovine mammary gland. Cornell Vet. 45 262.

4. Murphy J.M. 1959). The effect of certain mild stresses to the bovine teat canal on infection with Str, agalactiae. Cornell Vet. 35 41.

5. Baird-Parker, A. C. (1963) A classification of micrococci and staphylococci based on physiological and biochemical tests. J. gen . Microbiol. 30 409.

6. Davidson, I. (1961). A set of bacteriophages for typing bovine staphylococci. Res. Vet. Sci. 2 396.

7. Gleeson, E. J. O'Callaghan. Myles Rath (2004) Effect of liner design, pulsator setting, and vacuum level on bovine teat tissue changes and milking characteristics as measured by ultrasonography. Irish Vet J. Volume 57 (5) May 2004

8. Gehm, WJ. Comparison of Milk Flow Rates in Milking Systems International Dairy Topics Volume 8, Number 3

9. Evaluation of an Experimental Pulsation System, JDS 83:2004-2007

10. Gehm, WJ. Milking Machine Design and Mastitis, International Dairy Topics Volume 5, Number 4